Lasers in Surgery and Medicine 19:438–444 (1996)

In Vitro Pulp Chamber Temperature Rises Associated With the Argon Laser Polymerization of Composite Resin

Ivica Anić, DDS, PhD, Božidar Pavelić, MS, DDS, Berislav Perić, DDS, and Koukichi Matsumoto, DDS, PhD

Departments of Dental Pathology (I.A., B.P.) and Oral Surgery (B.P.), School of Dentistry, University of Zagreb, 10000 Zagreb, Croatia; Department of Endodontics, School of Dentistry, Showa University, Tokyo 145, Japan (K.M.)

Study Design/Materials and Methods: **This in vitro study was performed upon 50 extracted human molars that provided the occlusal surfaces for standard class I preparations. The cavity floor of the 20 specimens was covered with zinc phosphate cement and the teeth were sectioned transversally at or below the cemento-enamel junction. In some specimens pulp tissue was removed from the pulp chamber. The cavities of all specimens were filled with composite resin, and the resin was cured with an argon laser.**

Results: **A statistically significant difference in the rise in temperature was obtained only in the temperature of dentin roof of the pulp chamber between the specimens with (2.2°C) and without (3.1°C) cement base ($P < .05$). There was no significant difference in the temperature of the pulp tissue between specimens with (2.7°C) and without (2.2°C) base cement. The peak temperature of the composite surface was 13.8°C.**

Conclusion: **These data indicate that argon laser curing may be a method of choice for polymerization of the composite resin.**

Key words: composite polymerization, dental pulp, heat transfer

INTRODUCTION

Polymerization of composite resin is a potential source of exothermic temperature rise inside the composite mass and at the cavity floor [1]. The use of visible light to cure lining materials and/or composite resin has been shown to produce an attendant rise in the temperature of surrounding areas. Goodis et al. [2] found that when visible light-curing lamps were applied directly through the enamel and dentin and when they were used to cure a two-surface composite [3], the temperatures rose to levels where pulpal damage could occur. The visible light-activated composites usually contain diketone initiators such as camphoroquinone that is activated by wavelengths in the range of 400–500 nm. However, different composite resin materials may show a different temperature rises even though the resins have been cured by the same light generator. Furthermore, the use of the lamps by themselves causes a temperature rise within the pulp chamber that is proportional to the time of exposure [2]. Usually, it is not possible for practitioners to change the intensity of their chosen light source, although it is possible to vary the exposure time [4]. When using conventional lamps, the problem is that too short an exposure may lead to incomplete polymerization of composite resin. In addition, the thickness of the dentine between the cavity floor and the roof of the pulp chamber may influence the susceptibility of the intrapulpal region to harmful temperature elevations [5]. The thick-

Accepted for publication November 6, 1995.

Address reprint requests to Ivica Anić D.D.S., Ph.D., Department of Dental Pathology, School of Dentistry, University of Zagreb, Gundulićeva 5, 10000 Zagreb, Croatia.

ness of the residual dentin itself depends on extent of the dental caries. Practically, the practitioner may vary only the protective cement base materials limited to the ones that are reasonably good thermal insulators such as glass ionomers [6], or $Ca(OH)_2$ and zinc phosphate [7].

Heat production varies significantly among different lamps; thus overheating of the pulp tissue may be reduced with proper lamp selection [8]. The second option is to minimize the exposure time to the lamp of choice. However, shorter exposure time requires higher-intensity light. Recent interest has been expressed in increasing the application of lasers to restorative dentistry. The argon laser, emitting a primary wavelength of 488 nm, effectively polymerizes visible light–cured dental composite resin [9–11]. Furthermore, the laser polymerization may enhance the physical properties of resin restorative materials, and thus, the argon laser may be the method of choice [12].

The purpose of this study was to investigate the rises in temperature inside the pulp tissue and at the pulp chamber dentin roof following argon laser photopolymerization of class I composite resin fillings. The influence of the dentin thickness of the dentin overlaying the pulp chamber and the presence of the base cement on the temperature changes was also studied.

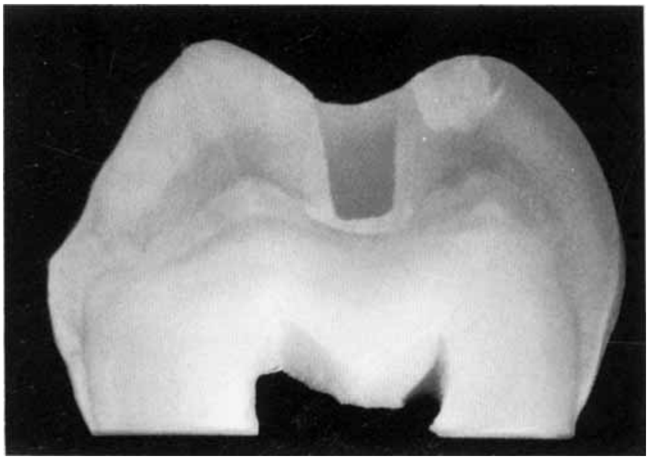

Fig. 1. The cavity filled with composite resin along the longitudinal section of the tooth crown.

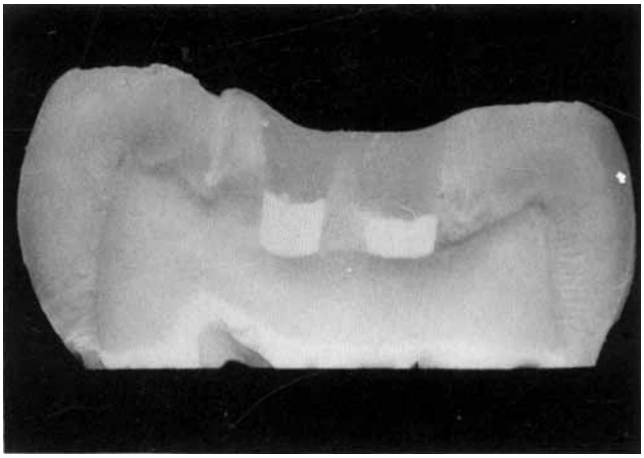

Fig. 2. The floor of the deeper cavity covered with zinc phosphate cement and composite resin.

MATERIALS AND METHODS

Fifty extracted, unerupted with mature apices or paritally erupted, caries-free human third molars were used. The teeth were stored in 10% formalin for 30 days. After that, the teeth were cleaned ultrasonically and then stored in physiological saline. Before the experiment, at the occlusal surfaces, the class I cavities were prepared with water-cooled diamond drills. The cavities were drilled as closely as possible to the same volume within the limits of manual procedure. The depth of the cavities was controlled with the color mark made on the diamond drill. The teeth were randomly divided into five groups of ten samples each. In the first two groups (A and B) the cavity floors were prepared at the enamelodeninal junction, and in the other three groups (C, D and E) the preparations were 2 mm below the junction. The cavity floor of the teeth in groups A, B, and E was not protected with cement base (Fig. 1). In contrast to this, the cavity floor in groups C and D (Fig. 2) was covered with zinc phosphate "GC Elite Cement" (GC Corp. Tokyo); thus the deeper cavities were prepared compared with the first two groups of samples. After hardening the cement base, the teeth from all groups were sectioned transversally at the cementoenamel junction using a low-speed saw "Isomet™" (Buehler, Lake Bluff, Illinois). The speed button control was set at position "3." At this stage, the residual pulp tissue from the pulp chamber was removed from the teeth in groups B, D, and E (Fig. 3). Figure 4 shows the bottom view of the remnants of the pulp tissue inside the pulp chamber in groups A and C. Immediately after cutting all the specimens were stored in physiological saline at 37°C for 15 min.

At the outset of the experiment, the test teeth were removed from their saline storage solution, and the occlusal surfaces were dried with

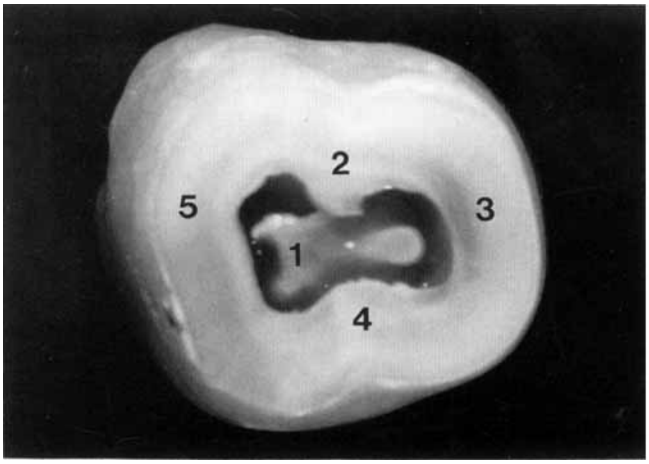

Fig. 3. The roof of the pulp chamber viewed through transversal cross-section surface. The numbers 1–5 indicate areas of measured temperature changes.

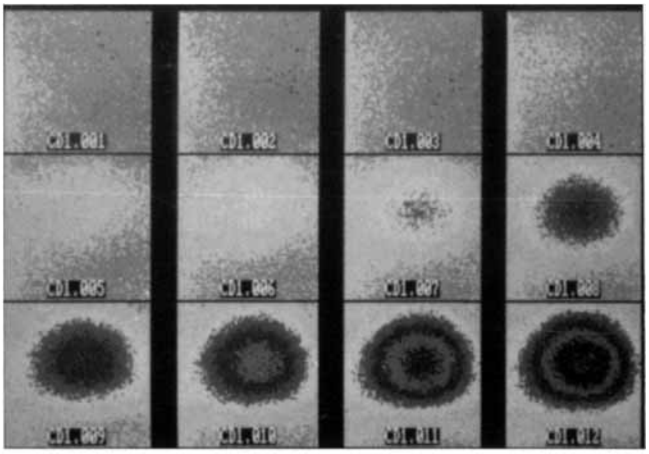

Fig. 5. Time-dependent computer image of spreading of the temperature across the pulp tissue and the dentin walls, recorded at the cross-section surface, 6 s before, during, and some time after lasing.

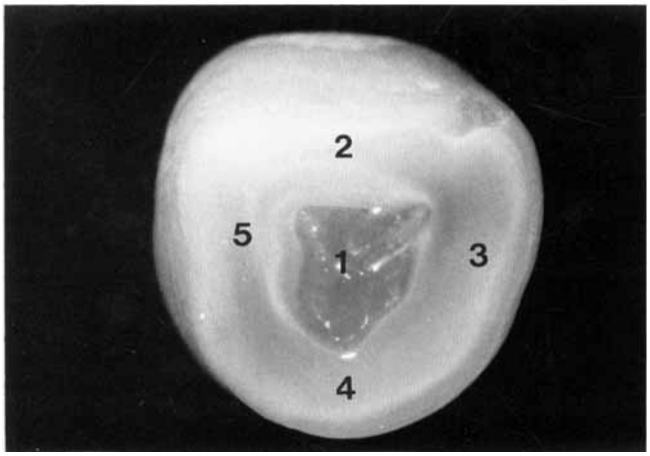

Fig. 4. The exposed pulp tissue remnants at the cross-section surface. The numbers 1–5 indicate areas of measured temperature changes.

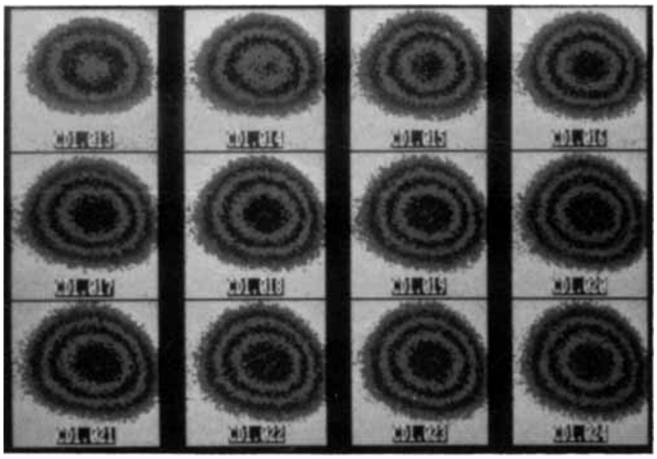

Fig. 6. Same as Figure 5.

air current. The enamel around the cavity was acid etched for 15 s with the 37% phosphoric acid gel. The etchant was then rinsed with water and surface dried with air. The cavity of each test tooth was covered with bonding agents. The agent was dispersed with air, and the cavity was then filled with a single layer of composite resin "Clearfil posterior" UL-color (Kurary Co., Ltd., Japan). The quantity of composite resin used for each preparation was standardized by filling a preliminary cavity and, upon removing the composite resin, forming it into a square-like shape (4.5 × 4.4 × 3.1 mm), followed by curing procedures. From this square model, a mold was created by embedding the vaseline-insulated model in self-curing acrylate resin. The acrylic mold was used to standardize the amount of composite (app 62 mm^3) that was used for filling the other cavities. The selected amount of the composite consistently resulted in mean values of 2.15 mm (S.D. 0.267) composite thickness. Any difference was a consequence of variety in the dimensions of the prepared cavity. After filling, the crown was inserted through the hole made in a 5-mm-thick cardboard wall such that the occlusal surface was directed toward a light source. The opposite side with exposed pulp chamber was inside the box directed toward a temperature measurement device. The composite resin was cured using the argon laser HGM (Medical Laser Systems, Salt Lake City, UT). The 488-nm-wavelength laser beam was delivered through a flexible quartz op-

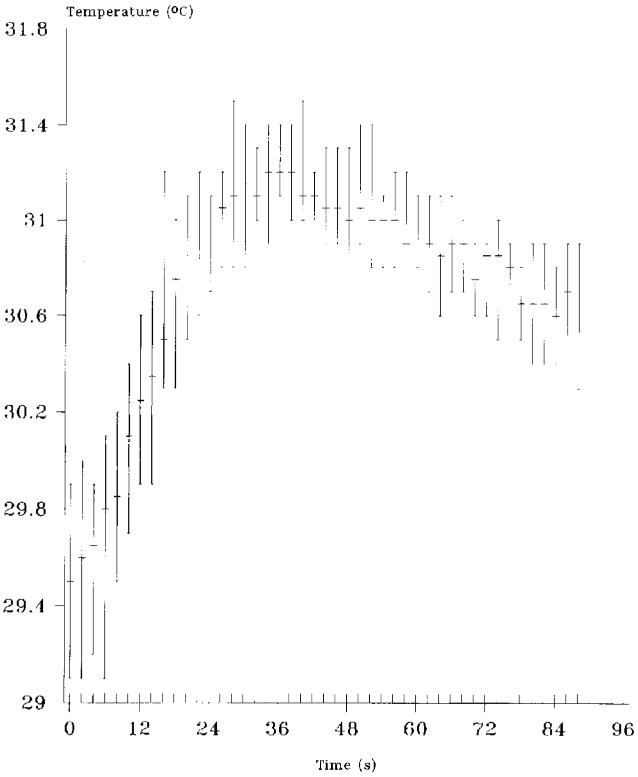

Fig. 7. Pulp chamber dentin roof temperature rises occurring during and after lasing of the composite with argon laser. The floor of the cavities was not covered with cement base.

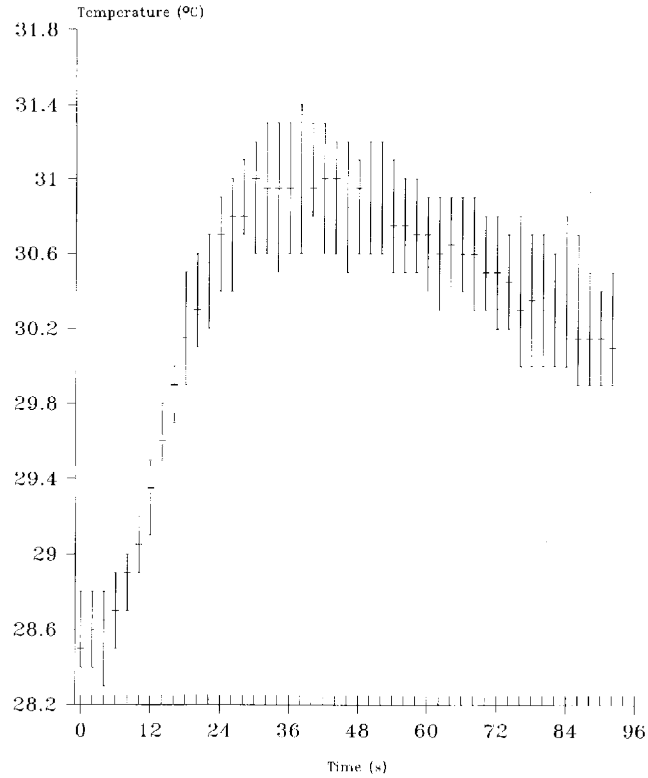

Fig. 8. Pulp chamber dentin roof temperature rises occurring during and after polymerization of the composite inside the cavities. Before the lasing, the floor of the cavities was covered with zinc phosphate cement.

tical fiber 300 μm in diameter. The fiber was operated manually in circular motions over the filling at a distance of approximately 2 cm. Three exposures were performed manually at a laser power of 1 W in continuous mode (CW), 5 s duration each, with a 2-s pause between pulses. According to the divergence angle of degrees, the spot size was ~1.50 mm in diameter at the impact spot. During the experiment, the room temperature was 25°C, and the cardboard minimized the influence of air flow around the specimen on the temperature. To monitor the pulp tissues' temperature changes during and after exposure of the resin to the argon laser, a thermovision camera (Thermovision 880 AGEMA Infrared Systems AB, Danderyd, Sweden) was positioned on the same level with the specimen at the focus distance. The data, recorded in real time, were stored on the PC hard disc and later analyzed using a Thermal Image Computer TIC-8000 system (AGEMA, Danderyd, Sweden). Five simultaneous temperature measuring regions were visualized on the TIC monitor, the first being at the projection of the pulp chamber, and the rest on the dentin walls surrounding the pulp chamber (Figs. 3, 4). During the temperature analysis, the monitor was fixed every 2 s to allow thorough screening of selected regions, thereby identifying those regions with the greatest temperature elevation.

After curing, the five crowns from each group were sectioned mesiodistally for every 1 mm, and the rest of the specimens were sectioned buccolingually for every 1 mm using the low-speed saw mentioned above. The dentin thickness between the floor of the preparation and the roof of the dental pulp was measured using an optical stereomicroscope and was recorded for the each sectioned specimen (mean values for groups A, C, and E were 2.52 mm (S.D. 0.290). At the same time, the composite thickness in all specimens and the thickness of the base materials in groups B and D were also measured (mean 1.42, S.D. 0.198).

Finally, the ten cavity samples from group E were packed with the composite resin and then cured three times with argon laser power of 1 W and 5 s duration of each pulse, using a 2-s interval between exposures. The temperature changes

were measured directly at the composite resin surface. To avoid the influence of the reflected laser beam on the accuracy of the thermovision camera, the temperature measurement was performed only before and immediately after laser action.

The data were analyzed based on the effect of the thickness of the dentin overlaying the pulp chamber and on the effect of the base cement on the temperature changes measured at the pulp chamber dentin roof or at the pulp tissue remnants. One-way analysis of variance was used to determine whether there were significant differences in temperature changes among the groups. Differences between means for each group were tested using Student's *t*-test.

RESULTS

The computer image of the heat spreading over the scanned area, recorded through the first 48 s of the measurement period, is shown on Figure 5 and 6. The highest temperature changes recorded at the pulp chamber roof of the samples without base cement (group B) was +3.1°C. This temperature was recorded after 36 s (Fig. 7). The peak temperature observed at the same site in groups with their cavity bottoms protected by cement base (group D) recorded at 24 s was +2.2°C (Fig. 8). There was statistical significance in the temperature rise between these two groups ($P <$ .05)

Figures 9 and 10 present the temperature ranges recorded at the pulp tissue surface positioned opposite to the roof of the pulp chamber in groups A and C. The peak temperatures recorded were 2.2°C and 2.7°C, respectively.

The composite resin surface cured with the argon laser (group E) demonstrated the highest temperature immediately after laser action was stopped (+13.8°C). An ensuing consistent decrease in temperature was recorded. After 94 s the temperature remained approximately 6°C higher than the starting temperature value (Fig. 11).

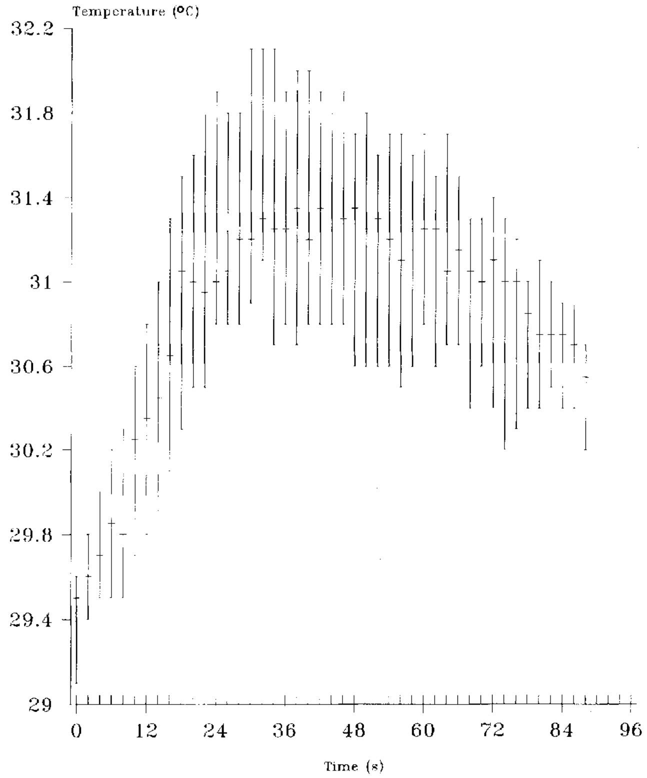

Fig. 9. Temperature changes recorded at the surface of the pulp tissues in the specimens without cement base.

DISCUSSION

The principal application of the argon laser to dentistry currently centers around the placement of the composite resin [13]. It has been shown that argon laser can improve the physical properties of composite resin, in particular, microfilled resin that tends to have a greater resin content. The complete curing can be achieved within only 25% of the standard visible light exposure time. Shanthala and Munshi [14] reported that laser use may be superior for the reason that it requires less time to obtain desired bond strength for both primary and permanent teeth. During argon laser photopolymerization of the composite fillings a rise in temperature occurs. The temperature rise is due to both the exothermic polymerization of the composite resin and the light energy [4]. As a consequence, a relatively high temperature developed at the composite resin surface and inside the mass. However, when argon laser is applied to a tooth or composite, the output of the laser can be quite different from the energy absorbed due to its reflectivity. It is interesting that the surface temperature developed and recorded in this study (13.5°C) following argon laser polymerization is almost twofold lower compared with 21.4°C reached in the case of same selected combination of composite and conventional light unit as reported by Lloyd [15]. However, the temperature changes were recorded after and not during lasing. When transversing the dentin, the heat can increase the dental pulp response and if the

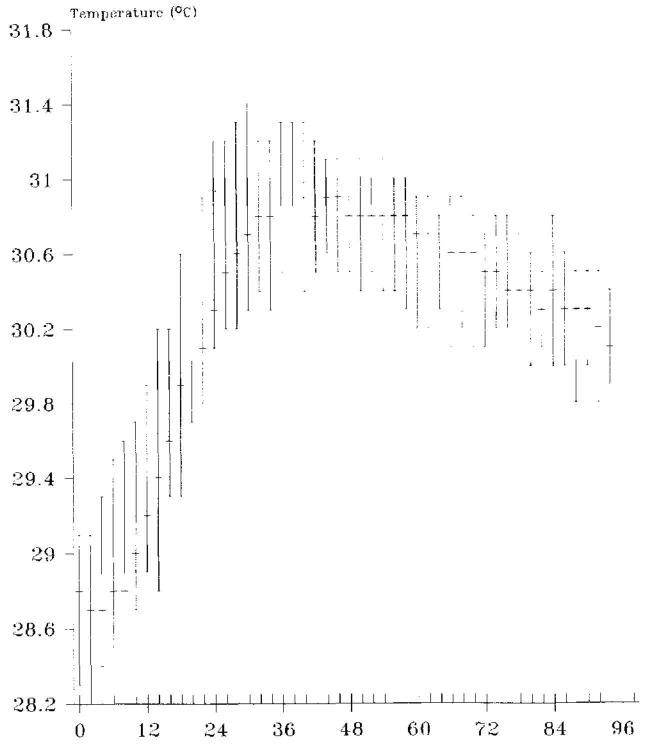

Fig. 10. Temperature changes recorded at the surface of the pulp remnants in the specimens in which the cavity floor was protected with zinc phosphate cement.

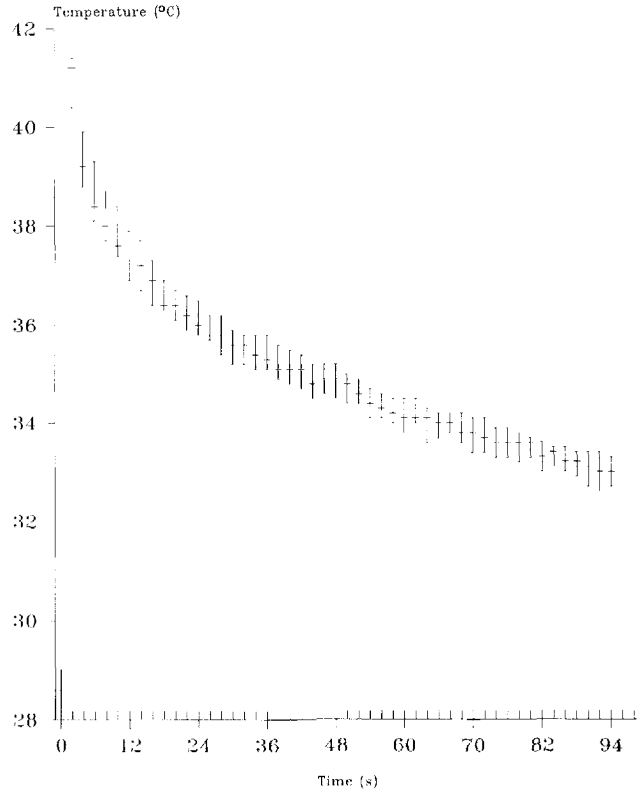

Fig. 11. Temperature changes recorded at the surface of the composite resin following argon laser polymerization.

thermal insult to the pulp is great enough, coagulation necrosis appears and, as a consequence, often develops into intrapulpal abscesses [16].

The relatively low rise in pulp tissue temperature of approximately +2.5°C recorded in this study can be explained by the shallow cavities and a relatively small amount of composite resin. Another explanation is that the dentin possesses low thermal conductivity. Furthermore, the cement base can influence significantly the rise in the temperature of the roof of the pulp chamber. This result can be compared with an average pulp temperature rise of 2.5°C obtained by Goodis et al. [8] using a combination of Heliolux lamp and light cured glass-ionomer (GI) liner. In contrast to this, the overheating may be a problem in a deep posterior cavity when using both a conventional lamp as well as an argon laser. This could be due in particular to the use of darker shade resins, for which a higher-intensity light source should be used [4]. To avoid pulp tissue overheating the pulp must be protected against thermal shock with cement base, and the composite should be cured in layers. However, if conventional lamps are used, such a procedure may result in a prolonged curing time. Smail et al. [5] reported that the presence of a primer layer of composite material may significantly decrease the rise in temperature. They also reported that even residual transmitted heat may cause pulpal damage. To prevent or to minimize transmission of both primary developing and residual heat, air cooling should be performed during and after lasing.

CONCLUSIONS

The temperature results obtained in this study indicate that the argon laser may be a method of choice for curing composite resin fillings in class I preparations. In deeper cavities, the base cement is necessary to prevent overheating of the dental pulp.

REFERENCES

1. Lloyd CH, Joski A, McGlynn E. Temperature rises produced by light sources and composites during curing. Dent Mater 1986; 2:170–174.
2. Goodis HE, White JM, Andrews J, Watanabe L. Measure-

ment of temperature generated by visible-light-cure lamps in an *in vitro* model. Dent Mater 1989; 5:230–234.
3. Goodis HE, White JM, Gamm B, Watanabe L. Pulp chamber temperature changes with visible-light-cured composites *in vitro*. Dent Mater 1990; 6:99–102.
4. Masutani S, Setcos JC, Schnell RJ, Phillips RW. Temperature rise during polymerization of visible light-activated composite resins. Dent Mater 1987; 4:174–178.
5. Smail SRJ, Patterson CJW, McLundie AC. In vitro temperature rises during visible-light curing of a lining material and a posterior composite. J Oral Reh 1988; 15: 361–366.
6. Tay WM, Braden M. Thermal diffusitivity of glass ionomer cements. J Dent Res 1987; 66:1040–1043.
7. Drummond JL, Robledo J, Garcia L, Toepke TRS. Thermal conductivity of cement base materials. Dent Mater 1993; 9:68–71.
8. Goodis HE, White JM, Marshall SJ, Koshrovi P, Watanage LG, Marshall, jr GW. The effect of glass ionomer liners in lowering pulp temperatures during composite placement, *in vitro*. Dent Mater 1993; 9:146–150.
9. Powell GL, Kelsey WP, Blankenau RJ, Barkmier WW. The use of argon laser for polymerization of composite. J Esthet Dent 1989; 1:34–37.
10. Blankenau RJ, Kelsey WP, Powell GL, Shearer GO, Barkmeier WW, Cavel WT. Degree of composite resin polymerization with visible light and argon laser. Am J Dent Assoc 1991; 4:40–42.
11. Blankenau RJ, Powell GL, Kelsey WP, Barkmeier WW. Post polymerization strength values of an argon laser cured resin. Lasers Surg Med 1991; 11:471–475.
12. Kelsey WP, Blankenau RJ, Powell GL, Barkmeier WW, Cavel WT, Whisenant BK. Enhancement of physical properties of resin restorative materials by laser polymerization. Lasers Surg Med 1989; 9:623–627.
13. Kelsey WP, Blankenau RJ, Powell GL. Application of the argon laser to dentistry. Lasers Surg Med 1991; 11:495–498.
14. Shanthala BM, Munshi AK. Laser vs visible-light cured composite resin: an in vitro shear bond study. J Clin Pediatr Dent 1995; 19:121–125.
15. Lloyd CH. A differential thermal analysis for the heats of reaction and temperature rises produced during the setting of tooth colored restorative materials. J Oral Rehabil 1984; 11:111–121.
16. Fraunhofer JA, Allen DJ. Thermal effects associated with the Nd/YAG dental laser. Angl Orthodon 1993; 63: 299–303.